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DISMANTLING RUSSIA'S NORTHERN FLEET NUCLEAR SUBMARINES: ENVIRONMENTAL AND PROLIFERATION RISKS

by

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June 2000

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DISMANTLING RUSSIA'S NORTHERN FLEET NUCLEAR SUBMARINES: ENVIRONMENTAL AND PROLIFERATION RISKS

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ABSTRACT

This thesis examines the 1986 Chernobyl accident and its consequences as the basis for an analysis of the possible dimensions of the nuclear catastrophes that could occur during the dismantlement process of Russia's Northern Fleet nuclear submarines. It assesses the potential demographic, ecological, and economic consequences of a nuclear accident. Given the systemic problems at Russian nuclear facilities, the risks of a catastrophic event in the poorly maintained and operated submarine yards housing over 100 operating nuclear reactors are significant. A major nuclear accident at these facilities could cause damage to the environment of global proportions. This thesis considers the potential environmental impact of a nuclear accident during the nuclear submarine dismantlement process and discusses the environmental damage that has already occurred as a result of Soviet and Russian practices. This thesis also evaluates the risk of diversion of nuclear materials to proliferators or terrorists. Lastly, this thesis examines how the United States, the European Union, and perhaps others could assist Russia in reducing the environmental and proliferation risks in this dismantlement process.

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EXECUTIVE SUMMARY

This thesis examines the 1986 Chernobyl accident and its consequences as the basis for an analysis of the possible dimensions of the nuclear catastrophes that could occur during the dismantlement process of Russia's Northern Fleet nuclear submarines. It assesses the potential demographic, ecological, and economic consequences of a nuclear accident. Given the systemic problems at Russian nuclear facilities, the risks of a catastrophic event in the poorly maintained and operated submarine yards housing over 100 operating nuclear reactors are significant. A major nuclear accident at these facilities could cause damage to the environment of global proportions.

This thesis examines the current dismantlement process that takes place at the Nerpa Shipyard, the Northern Machine Building Enterprise (Sevmash), and the Zvezdochka shipyards in Severodvinsk. It considers the potential environmental impact of a nuclear accident during the dismantlement process and discusses the environmental damage that has already occurred as a result of Soviet and Russian practices. This thesis also evaluates the risk of diversion of nuclear materials to proliferators or terrorists. Lastly, this thesis examines how the United States, the European Union, and perhaps others could assist Russia in reducing the environmental and proliferation risks of this dismantlement process.

Towards the end of 1998, the Russian Navy had retired nearly 170 nuclear-powered submarines from its inventory. Of those 170 submarines, the dismantlement process had been completed on only 40. Of those still awaiting dismantlement, 110 to

115 still had operating reactors and nuclear fuel on board. This situation has remained virtually unchanged.

The dismantlement process takes place at one of the three port facilities located on the Kola Peninsula. The Kola Peninsula, from the Arctic and Norwegian Seas to the depths of the White Sea, is dotted with Northern Fleet naval bases and naval shipyards. These facilities are home to approximately two-thirds of Russia's nuclear- powered submarines and the associated problems of managing their radioactive waste. Russia's capacity to dismantle these vessels, however, is limited because of economic problems. By 1999, the downward spiral of Russia's economy and political immobilism had created a nuclear "nightmare" in the Northern Fleet. Submarines designed to operate for twenty years are being decommissioned early and at an alarming rate. Older first- and second-generation submarines are being laid up for years due to the lack of financing and the inability to carry out safe dismantlement. These submarines are creating a bottleneck of "dying" nuclear-powered submarines of potentially catastrophic proportions.

ACKNOWLEDGEMENTS

The author would like to express his thanks to the many people behind the scenes. First to Dr. David Yost, whose expertise and experience was instrumental in the completion of this thesis. To Ambassador Rodney Minott, whose wisdom and guidance has led me to challenge the parochial nature of the status quo. Finally, to my wife Rachelle for her loving support and enduring patience without which this research could not have been completed.

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I. INTRODUCTION

This thesis examines the 1986 Chernobyl accident and its consequences as the basis for an analysis of the possible dimensions of the nuclear catastrophes that could occur during the dismantlement process of the Northern Fleet nuclear submarines. It assesses the potential ecological and economic consequences of a nuclear accident. Given the systemic problems at Russian nuclear facilities, the risks of a catastrophic event in the poorly maintained and operated submarine yards housing over 100 operating nuclear reactors are significant. A major nuclear accident at these facilities could cause damage to the environment of global proportions.

This thesis examines the current dismantlement process that takes place at the Nerpa Shipyard, the Northern Machine Building Enterprise (Sevmash), and the Zvezdochka shipyards in Severodvinsk. It considers the potential environmental impact of a nuclear accident during the dismantlement process and discusses the environmental damage that has already occurred as a result of Soviet and Russian practices. Additionally, this thesis evaluates the risk of diversion of nuclear materials to proliferators or terrorists. Lastly, this thesis examines how the United States, the European Union, and perhaps others, could assist Russia in reducing the environmental and proliferation risks of this dismantlement process.

A. BACKGROUND

Towards the end of 1998, the Russian Navy had retired nearly 170 nuclear-powered submarines from its inventory. Of those 170 subs, the dismantlement process had been completed on only 40. Of those still awaiting dismantlement, 110 to 115 still

had operating reactors and nuclear fuel on board.[1] This situation has remained virtually unchanged.

The dismantlement process takes place at one of the three port facilities located on the Kola Peninsula. Russia's capacity to dismantle these vessels, however, is limited.

> Russia's current inability to handle the nuclear materials resulting from the dismantlement process further complicates the situation. These unexpected challenges...present severe financial drains on the Russian federal budget....Russia's economic crisis has only exacerbated its inability to address the problems properly.[2]

Moscow officials have admitted that the rapid decommissioning of the Northern Fleet, specifically its submarine force, has worsened the situation by creating a huge backlog of units that require dismantlement. Under the current system, only three to six submarines can be dismantled per year.

Since the Russian economic crisis in August 1998, the dismantlement process has come to a near standstill. "Yet, keeping decommissioned submarines afloat as they await dismantlement demands a partial crew to provide general maintenance, oversee the reactor cooling system, and guarantee safety levels....[at a]cost [of] $200,000 per sub per year."[3]

For economic reasons, Russia has deemed the nuclear submarine dismantlement process a low priority. This decision has made the Kola Peninsula, the Scandinavian

1 James Clay Moltz, Report on the Conference on "Perspectives on International Cooperation in the Dismantlement of Nuclear Submarines," Moscow, Russia, 11 December 1998.

2 Tamara C. Robinson, "Submarine Dismantlement and Material Storage Challenges for Russian Nuclear Propulsion," (Prepared for a conference at the Naval Postgraduate School, Monterey California, 16-17 March 1999) Monterey Institute of International Studies, 2.

3 Ibid., 11.

countries, and to a large degree the Northern Hemisphere vulnerable to an ecological catastrophe.

The Chernobyl case is relevant to this thesis as an illustration of the potential seriousness of nuclear accidents in the former Soviet Union. The 1986 Chernobyl nuclear reactor accident has caused at least fifty thousand deaths to date. Additionally, the heavily contaminated areas of Ukraine and Belarus will remain uninhabitable for years to come. Furthermore, the radioactive cloud that emitted continuously for some 15 days from the burning graphite RBMK-1000 reactor spread its deadly poison over much of the European and Asian continents.

The immediate concern was the risk of contamination of the fresh food supply. Concentrations of certain radioactive isotopes in the food chain necessitated, for example, the destruction of reindeer herds in Finland and Sweden.

After some delay the Soviet government informed the public of the catastrophe and began evacuating the population. The Soviet government downplayed the seriousness of the situation presumably to reassure its own citizenry, but at the same time marshaled its vast bureaucratic forces to "cover up" the consequences of the accident.

The scale and severity of the Chernobyl accident with its widespread radioactive contamination had not been foreseen and took by surprise most national authorities responsible for emergency preparedness. No provisions had been made for an accident of such a scale. Though some radiation protection authorities had made criteria available for intervention in an accident, these criteria were often incomplete and provided little practical help in these circumstances. Few workable national guidelines or principles were therefore actually in place. Local emergency response teams, unprepared for

nuclear catastrophe, were the first to respond to the accident. These local emergency response teams reacted in accordance with training for conventional emergencies rather than being directed by the informed scientific and expert judgement of trained nuclear response teams.[4]

The Chernobyl disaster thus serves as an appropriate case study of what could happen without a cohesive and organized plan to deal with the potential catastrophes during the dismantlement process of the Russian Northern Fleet nuclear submarine force.

B. METHODOLOGY

This thesis is based on an analytical survey of primary and secondary sources concerning the dismantlement process of Russian nuclear submarines, the actual and potential effects of this process on the environment, and the efforts of external powers to assist Russia in dealing with this situation. A case study of the Chernobyl accident is used to provide background information about a nuclear accident of significant gravity that may be attributed, at least in part, to procedures similar to those involved in the nuclear submarine dismantlement process. Additionally, interviews were conducted with leading experts in the fields of nuclear reactor dismantlement, nuclear proliferation, ecology, and foreign policy. This thesis analyzes various aspects of the dismantlement process and identifies potential solutions.

C. THESIS ORGANIZATION

Chapter II examines the conditioning factors of the Chernobyl accident, the actors, the response, and the environmental impact of the Chernobyl disaster. Chapter III

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4 "The Chernobyl Nuclear Accident and its Ramifications," *Nuclear Energy Agency,* Available [Online]: <http://www.infoukes.com/history/chornobyl/idex.html. [24 August 1999].

discusses the current status and condition of the dismantlement process and the Northern Fleet submarines involved. Additionally, it considers the challenges and problems associated with the dismantlement process. Chapter IV discusses the current environmental damage as a result of the dismantlement process, the non-proliferation risks involved with the process, and the potential for further environmental damage. Chapter V surveys the external assistance provided to Russian efforts and provides recommendations in support of safe and efficient management of the dismantlement process. Additionally, Chapter V offers conclusions about the importance of improving this process, in view of the potential for environmental damage of global proportions.

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II. CHERNOBYL: A CASE STUDY

A. THE ACCIDENT AND ITS CONDITIONING FACTORS

On 26 April 1986 an accident occurred at the fourth unit of the Chernobyl nuclear power station in Ukraine, then part of the Soviet Union, which resulted in the destruction of the reactor core and part of the building in which it was housed. Large amounts of the radioactive material were released into the surrounding environment. Hot materials were expelled, starting fires that exacerbated the situation and lifted more radioactive material high into the air.

> Although the most intense releases of radioactivity were shortly after the accident, there were large releases 20-21 days and 25-30 days after the accident attributed to new local releases from "heated zones" of the reactor.[5]

The accident at Chernobyl occurred during a test being carried out on a turbogenerator at the time of a normal scheduled shutdown of the reactor. This was intended to test the ability of the turbogenerator, during station blackout, to supply electrical energy for a short period until the standby diesel generators could supply emergency power. The test procedures were improperly written from the safety point of view, and serious violations of basic operating rules put the reactor at low power (200 MW (th)) operation in coolant flow rate; and the cooling conditions could not be stabilized by manual control. "The major factor contributing to the accident was a severe violation of operating rules by personnel, which put the reactor operation in an unsafe

5 Don J. Bradley, *Behind the Nuclear Curtain: Radioactive Waste Management in the Former Soviet Union* (Columbus:Batelle Press, 1997), 345.

regime."[6] Subsequent events led to the generation of an increasing amount of steam voids in the reactor core, thereby introducing positive reactivity. The beginning of an increasingly rapid rise in power was seen, and a manual attempt was made to stop the chain reaction. However, the manual trip, which the test would have triggered earlier, had been blocked. Consequently, the possibility of a rapid shutdown of the reactor was limited, as almost all the control rods had been withdrawn completely from the core. Soviet experts calculated that, due to continued reactivity, the first power peak reached 100 times nominal power within four seconds.

Energy released in the fuel by the power excursion suddenly ruptured part of the fuel into minute pieces. Small hot fuel particles (and possibly also evaporated fuel) caused a steam explosion. The energy release shifted the 1000-ton reactor cover plate and resulted in all cooling channels on both sides of the reactor cover being cut. After two to three seconds an additional explosion was heard, and hot pieces of the reactor were ejected from the destroyed reactor building.

B. ACTORS AND RESPONSE

According to Robert Ebel's authoritative account,

- Local staff did not realize the enormity of events at Chernobyl. The magnitude of the disaster became clear only when authorities arrived from Moscow the evening of the first day.

- Early reports from local authorities to Moscow seriously understated the disaster. Later on, information was deliberately withheld to prevent panic in Kiev, a city of some 2.3 million located south of Chernobyl.[7]

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6 Ibid., 345.

7 Robert Ebel, *Chernobyl and Its Aftermath: A Chronology of Events* (Washington, D.C.: Center for Strategic and International Studies, 1994), 2.

The national authorities in Moscow were alerted about the accident on 26 April and a specialist team was immediately dispatched to the site to assist local authorities and plant management to deal with the situation. Initially there were problems in accurately reporting the severity of the accident at the plant and off-site.

On their arrival, the specialist team found a very serious situation. One of the initial decisions was that a precautionary evacuation of the town of Pripyat should be carried out as soon as possible. "The USSR had no 'ready to go' evacuation plans pertaining to nuclear power plants."[8]

All the protective measures and deployment of resources and personnel were ordered and coordinated by a special commission. Decontamination procedures performed by military personnel included washing buildings, cleaning residential areas, removing contaminated soil, cleaning roads, and decontaminating water supplies. Special attention was paid to schools, hospitals, and other buildings used by large numbers of people. Streets were watered down in towns to suppress dust.[9]

The removal of radioactive dust from the roof of unit No. 4 was performed by the military as well. Sophisticated remote-controlled equipment, some of it imported from West Germany and other countries, could not do the job. Electronic circuits failed due to the effects of radiation. Later, tractor robots were used on the roof, their sophisticated electronics having been replaced with conventional relays.[10] Ultimately, however,

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8 Ibid., 1.

9 "The Chernobyl Nuclear Accident and its Ramifications," Nuclear Energy Agency.

10 Robert Ebel, 24.

soldiers using wheelbarrows and working in 90-second shifts to minimize their exposure to the lethal radioactive dust performed the cleanup.[11]

Personnel seriously ill from radiation were sent to Moscow Hospital number 6.

> Western doctors remarked on the sophistication shown by the staff in handling radiation burns, surmising that this could only have come from experience. Their observations tended to confirm suspicions of a major nuclear accident in the Urals, a long kept secret, during the winter of 1957-1958. Moscow now admits that an accident did take place. Evidence suggests that the accident was more damaging than the blast at Chernobyl.[12]

As Robert Ebel has noted, "Following the explosion at Chernobyl, international help was offered to the USSR, but limited amounts were accepted."[13] Western European countries provided supplies and equipment to fight the fire, and remote-controlled equipment for the cleanup.

Although the emergency response had to be initiated at the local level, the management of the emergency situation required a rapid acceleration of resource commitments. Because of the scale of the accident, such resources, and the authority for their commitment, could not be expected to exist at the local level.

C. ENVIRONMENTAL IMPACT

As Zhores Medvedev has observed, "Fall-out from the Chernobyl accident was detected in every country of the Northern Hemisphere."[14] While the Soviet Union sustained the most serious contamination, livestock and crops outside the USSR were

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11 Ibid.

12 Ibid., 3.

13 Ibid., 1.

14 Zhores A. Medvedev, *The Legacy of Chernobyl* (New York: W. W. Norton & Company, 1990), 220.

affected. The areas of the heaviest contamination remain off limits to their former residents and will be for many years to come.

While it is still too early to gauge the long term effects of the disaster, projections based on the amount of radiation received by different populations predict a measurable increase in the cancer rate within the heavily contaminated areas and a statistically insignificant increase throughout the Northern Hemisphere.

> The radionuclide contaminants of most significance in agriculture are those which are relatively highly taken up by crops, have high rates of transfer to animal products such as milk and meat, and have relatively long radiological half-lives.... The major radionuclides of concern...are iodine 131, caesium-137, caesium-134, and strontium 90.[15]

Cesium^{137} (^{137}Cs) is the primary long-term contaminant because of the amount of radionuclides released. Cesium^{137} damages the body during ingestion and inhalation, and through absorption as background radiation from contaminated areas.[16] However, the amount of ^{137}Cs contamination in the body will decrease over time. The official United States estimate for the amount of ^{137}Cs released from Chernobyl was three million curies, distributed as follows: one third in the former Soviet Union, one third in Europe, and the final third throughout the Northern Hemisphere.[17]

Conversely, ^{90}Sr, with a thirty-year half-life, is regarded as a more serious threat than ^{137}Cs. According to Medvedev,

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15 "Chernobyl, Ten Years On" *National Energy Agency*. Available [Online]:<http://www.nea.fr/html/rp/ reports/1995/chernobyl/allchernobyl.htm. [19 August 1999]. 44-45.

16 Medvedev, 167-178.

17 Ibid., 211.

Soviet regulators treat ^{90}Sr more seriously than ^{137}Cs because it becomes fixed in bones for the rest of human life if it gets into the food chain. It is therefore leukaemogenic.[18]

Iodine ^{131} (^{131}I) has a half-life of a little over one week. Even with its short half-life, ^{131}I is the primary cause of thyroid cancer because that gland attracts iodine. The dumping of milk throughout Europe and the Soviet Union was primarily due to ^{131}I contamination. Children are highly susceptible to thyroid cancer because the gland is still growing. The primary route to the thyroid is through ingestion of milk and fresh vegetables.[19] These contaminants became so densely concentrated in certain areas that they were designated exclusion zones.

The only country that had to resort to exclusion areas was the Soviet Union. About 4,700 km^2 of land is still off limits to personnel, 2,600 km^2 in Belarus and 2,100 km^2 Northwest of the Chernobyl power plant.[20] ^{137}Cs to an extent greater than 37,000 Bq/m^2 contaminated 125,000 km^2 of land in what is now the former Soviet Union.[21] Of that land, over 52,000 km^2 was under cultivation.[22] Ironically, Chernobyl is located in Ukraine, which was the breadbasket of the Soviet Union.

Over 100,000 people from the Chernobyl area have been permanently resettled, but 275,000 continue to live in highly contaminated areas.[23] The population that is still

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18 Ibid., 178.

19 "Chernobyl, Ten Years On," *National Energy Agency*. 36-37.

20 Ibid., 46.

21 Ibid., 45.

22 Ibid.

23 Ibid., 32.

living in the contaminated areas has already absorbed **a** maximum accumulated dose of 25 rem. To avoid moving these people, the Ukrainian government has **raised** the maximum permissible dose to 35 rem.[24]

European countries received contamination due to local precipitation that brought the radioactive contaminants back to earth. Scandinavia and the United Kingdom were the hardest hit. In the United Kingdom, 475,000 sheep could not be sent for slaughter due to excessive levels of contaminants in 1987.[25] 170,000 reindeer were heavily contaminated and another 300,000 were lightly contaminated in Northern Scandinavia, and 50,000 were destroyed to avoid contamination of the local population. This nearly destroyed the ancient traditions of the Lapp nation.[26]

> If, as some officials had initially intended, the contaminated herds had been destroyed, the Lapps would almost certainly have been assimilated with the Swedes, Finns and Norwegians.[27]

The reindeer were affected due to their diet of lichen; this plant has no roots and gets its nutrients from the surface and is thus easily contaminated. It is estimated that ^{137}Cs levels in the reindeer population will not fall below 1000 kBq/kg for thirty-six years.[28]

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24 Medvedev, 186.

25 Ibid., 218.

26 Ibid., 199.

27 Ibid.

28 Ibid.

The original limit for ^{137}Cs contamination was 300 kBq/kg, but the Swedish government raised the maximum level to 1,500 kBq/kg to allow consumption by the migratory population that relies on the reindeer for food.[29]

Fifteen percent of the Swedish lakes were also contaminated, thus putting them off limits to fishermen for decades.[30] The Swedes also identified localized pockets of contamination in the south and had to destroy crops, pastures, and milk supplies to avoid contaminating the local populations.

The full story of Chernobyl's health effects may never be accurately known due to Soviet secrecy, the amount of territory affected, and the unparalleled amount of radiation released. Scientists estimate that Chernobyl's release of radiation exceeded Hiroshima and Nagasaki, combined, by more than two hundred times.[31] One of the few facts that is certain about Chernobyl is that thirty-one plant workers and firefighters lost their lives in the explosion and resulting fire. Three died in the explosion, and the other twenty-eight died of acute radiation poisoning. Of the 499 persons observed at area hospitals after the explosion, 237 were immediately diagnosed with radiation sickness.[32]

According to David Marples, director of the Stasiuk program on Contemporary Ukraine:

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29 Medvedev, 199.

30 "Chernobyl, Ten Years On" *National Energy Agency*. 48.

31 "Chernobyl Status, April 1997." Available [Online]:<http//www.greenpeace.org/~comms/97 /nuclear /reactor/chern11.html. [14 August 1999]. 2.

32 "Chernobyl, Ten Years On," *National Energy Agency*. 34.

> I have encountered totally undocumented estimates as high as 125,000 deaths among these workers.... Of these, at least 5,000 had died **by** 1990.... The National Committee for Radiation Protection of the Ukrainian Population recently issued what appear to be reliable figures, indicating that 5,772 liquidators [workers] have died.[33]

In his book *Chernobyl: A Documentary Story,* Lurii Scherbak recounts a truly heroic tale of the first people to arrive at the explosion. Of all the eyewitness accounts of ambulance drivers, firefighters, and plant personnel, the most amazing concern the actions of the initial firefighters. Through overwhelming bravery and dedication or a lack of understanding about radiation, these first crews put themselves in the most dangerous situation, immediately climbing directly over the exposed core to fight the fire that blazed below them. Every one of these firefighters was dead within a week.[34]

Not all of the people whose health was affected by Chernobyl died. Many medical studies have focused on other health problems experienced by people living near the power plant. Unfortunately, poor pre-explosion records were kept for that population, so many conclusions reached by these studies are educated guesses at best. Still, there seems to be no doubt about radical increases in some cancer rates.

In Belarus, for example, the lung cancer rate for those evacuated from Chernobyl was four times the average of the rest of the population.[35] On the basis of the national statistics of Belarus, UNICEF has concluded that bone marrow, muscle tissue, and

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33 David R. Marples, "Chernobyl's Toll After 10 Years." *Bulletin of the Atomic Scientist.* May/June 1996 Issue. Available [Online]:<http://www.bullatomsci.org/issues/1996/mj96/marplesoped.html. [12 August 1999]. 1.

34 Lurii Shcherback, Chernobyl: A Documentary Story (Canadian Institute of Ukranian Studies, 1989), 37.

35 David R. Marples, "Chernobyl's Toll After Ten Years." 1.

connective tissue system disorders have increased sixty-two percent, while malignant tumors have increased thirty-eight percent. Perhaps the most dramatic development has been the 100-fold increase in thyroid cancer in children.[36]

According to the Institute of Radiation Medicine,

> The appearance of thyroid tumors among children in the contaminated zones had made a sudden and dramatic appearance, increasing in Belarus by more than five times between 1989 and 1990. All the children were born shortly before or during the time of the Chernobyl disaster. There is a clear correlation between these cancers and Chernobyl-produced radiation.[37]

The number of thyroid cancer cases continues to rise. The World Health Organization estimates that one in ten children who lived in the contaminated zone will develop thyroid cancer, which would equate to roughly 10,000 cases. In the years since Chernobyl, both Belarus and Ukraine have experienced negative population growth.[38] The causes of these declines in population probably involve factors in addition to Chernobyl, however. Post-Soviet Russia has also experienced population declines, and many factors other than radiation appear to have contributed to these demographic shortfalls.[39]

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36 "Chernobyl Status, April 1997." 2.

37 David R. Marples, "Chernobyl's Lengthening Shadow," *The Bulletin of Atomic Scientist*. Sep. 93 issue. Available [Online]:<http://www.bullatomsci.org/issues/1993/s93Marples.html. [12 August 1999]. 5.

38 David R. Marples, "The facts about the aftermath," *Ukrainian Weekly*. No. 16, Vol. LXIV (April 26, 1996). Available [Online]:<http://www.ukweekly.com/Archive/1996/169610.html. [1 Sept 1999].

39 Nicholas Eberstadt, "Russia: Too Sick to Matter," *Policy Review*. June/July 1999, No 95. Available [Online]:<http://www.policyreview.com/jun99/eberstadt.html.

David Marples sums up the environment and health affects of Chernobyl as follows: "the scale of the problem is reminiscent of the rebuilding after the German-Soviet war."[40]

D. CONCLUSION

The explosion of reactor No. 4 at the Chernobyl Nuclear Power Plant had both immediate and long-term effects on the health of the people who came into contact with the deadly radiation. In the entire previous history of nuclear power plants only 620 persons had been exposed to acute radiation (defined as greater than 6.0 Gy), of whom 33 died. At Chernobyl, over 24,500 people were exposed to acute radiation.[41] Though accounts vary, most estimates of Chernobyl's death toll are in excess of 10,000 people, with more expected. Many have moved back into the contamination zone and will therefore continue to experience the harmful effects of radiation. Scientists and medical experts predict the explosion's immediate effects will continue to harm human health until the youngest people alive on 26 April 1986 eventually die off. The enduring effects of the explosion will, to be sure, last for many more years, as noted above.

Was the Chernobyl accident an isolated incident? How significant are the risks of another nuclear incident and further environmental damage in the former Soviet Union? At a press conference held on 25 April 1997, the day prior to the eleventh anniversary of the Chernobyl accident, Vladimir Slivyak, an analyst with the Socio-Ecological Union, gave a report regarding the present status of the nuclear industry in Russia.

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40 David R. Marples, "Chernobyl's Lengthening Shadow," 3.

41 David Mould, *Chernobyl: The Real Story* (Oxford and New York: Pergamon Press, 1988), 152.

> According to updated information submitted by the Russian State Radiation Control Authority (GAN), 11 incidents were reported at Russian nuclear power plants (NPPs) during January 1997. In 1994 there were 126 incidents, sinking to 99 in 1995. One main reason for the low 1995 number was the fact that some of the 9 reactor installations were under repair during that year. According to GAN only some 30% of the planned safety improvement measures at the reactor installations were completed by the end of 1996.[42]

The accidents and incidents at these nuclear power plants are not limited to the RBMK type of nuclear reactor associated with Chernobyl. Rather, they involve all the nuclear reactors in the Russian inventory, including the reactors in nuclear submarines of the Northern Fleet undergoing the dismantlement process on the Kola Peninsula. The management, storage, and handling of nuclear materials associated with the nuclear submarine dismantlement process may present the greatest danger of another "Chernobyl-like" accident.

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42 Status of the Russian Nuclear Power Plants." Bellona (28 April 1997): Available [Online]:<http://www.bellona.no/e/russia/incidents.html. [10 September, 1999]. Pagination of this document is impossible because it is frequently updated. This applies to all www.bellona.no references in this thesis.

III. CURRENT STATUS OF THE DISMANTLEMENT PROCESS

A. INTRODUCTION

For more than 40 years the Soviet Union and the United States engaged in a Cold War based in part on ideological conflict. This conflict was the catalyst for an arms race that proceeded with little to no long term planning or preparation for its aftermath. One of the aspects of this competition was the building of each nation's nuclear submarine force. By the end of 1994, the Soviet Union and its principal successor state, Russia, had constructed a total of 245 nuclear submarines.[43] The majority of these submarines contain two nuclear reactors.

Soviet Russia had four main fleets, but the Northern Fleet became the largest and most important because of its ice-free ports, its geographic location, and its large nuclear submarine force.[44] It also became the fleet with the greatest potential for a nuclear environmental catastrophe.

The Northern Fleet's nuclear submarines operate out of five naval bases on the Kola Peninsula: Zapadnaya Litsa, Vidyayevo, Gadzhievo, Severmorsk, and Gremikha. Additionally, these bases have numerous facilities for operating nuclear vessels, for storing various levels of solid and liquid radioactive waste (SRW and LRW), and for

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43 Jill Tatko and Tamara Robinson, "Naval Nuclear Vessels Overview," Monterey Institute of International Studies, 1999. Available [Online]:<http://www.cns.edu/db/nisprofs/russia/naval/overview.htm. [2October 1999].

44 Jill Tatko and Tamara Robinson, "Northern Fleet Overview," Monterey Institute of International Studies, 1999. Available [Online]:<http://www.cns.edu/db/nisprofs/russia/naval/nucflt/norflt/norflovr.htm. [2 October 1999].

land-based storage of spent fuel assemblies.[45] The Northern Fleet also utilizes six naval yards on the Kola Peninsula: Nerpa, Safonovo, Sevmorput, and Shkval in the Murmansk region, and Sevmash and Zvezdochka in the Arlangelsk region.[46] It is important to understand the location of these bases and shipyards because of the proximity of their radioactive material to populated areas, and to the Barents Sea, the White Sea, and the Arctic Ocean.

B. ENVIRONMENTAL LAYOUT OF RUSSIAN NAVAL BASES

Zapadnaya Litsa, located forty-five kilometers from the Norwegian border on the Barents Sea, is the largest submarine base in Russia, housing nearly twenty-five submarines. There are four additional naval facilities associated with this base: Andreeva Bay, Bolshaya Lopatka, Malaya Lopatka, and Nerpicha. The city of Zaozersk (population 30,000) supports the naval base and its facilities.[47]

1. Andreeva Bay

Andreeva Bay is located about five kilometers from Zaozersk, on the west side of the Litsa Fjord. Although there are no nuclear-powered submarines based there, it is the primary storage facility for the Northern Fleet's radioactive waste and spent nuclear fuel. "A total of 21,000 spent nuclear fuel assemblies and about 12,000 m^3 of solid radioactive

45 Bradley, 241-242.

46 Ibid., 242.

47 Ibid., 244-247.

waste and liquid radioactive waste are stored at Andreeva Bay. This figure also includes contaminated equipment and construction material still remaining in Building 5."[48]

2. Bolshaya Lopatka

Bolshaya Lopatka, located on the other side of the Litsa Fjord from Andreeva Bay, has eight piers and a servicing dock for submarine storage and repair. There is about 2 m^3 of solid radioactive waste stored here, as well as a smaller storage facility for liquid radioactive waste. When these storage facilities are full, the excess waste is transported to Andreeva Bay.[49]

3. Malaya Lopatka

Malaya Lopatka, located two kilometers from Bolshaya Lopatka, was the first naval facility constructed for the repair and servicing of nuclear-powered submarines. There are five piers and a floating dock for such maintenance.[50]

4. Nerpicha

Nerpicha is the innermost naval facility of the Zapadnaya complex. Its submarine piers were available in the 1970s. The six Typhoon SSBNs are currently based here. There are also storage facilities for solid and liquid radioactive waste. These facilities are rather small, so radioactive waste is continuously transported to Andreeva Bay.[51]

Vidyayevo naval base consists of two additional naval facilities: Ara Bay and Ura Bay. It became a facility for nuclear-powered submarines in 1979. There are currently

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48 Ibid., 245. Specifics concerning the problems associated with radioactive waste storage at the Northern Fleet facilities are addressed in Chapter IV of this thesis.

49 Ibid., 247.

50 Ibid.

fourteen nuclear-powered submarines, containing twenty-three fueled reactors, laid-up[52] in Ara Bay. Additionally, there are small storage facilities for SRW and LRW. Three partially constructed tunnels at Ara Bay, initially designed to conceal submarines, are in the planning stages to become an interim repository for nuclear reactors and radioactive waste.[53]

Gadzhievo also consists of two additional naval facilities: Sayda Bay, formerly the fishing village of Gadzhievo, and Olenya Bay. As of 1995, Sayda Bay housed twelve nuclear-powered submarines and twelve reactor compartments at its three piers. An additional reactor compartment containing twenty tons of SRW was expected in 1996. Nuclear-powered submarines have been stationed at Gadzhievo since the early 1960s, primarily because of the facilities for removing spent nuclear fuel. There are 200 m^3 of LRW and 2,037 m^3 of SRW stored at various facilities throughout the base. There are nine submarines based at Olenya Bay, six of which are laid-up for dismantlement.[54]

Severmorsk, located twenty-five kilometers north of the city of Murmansk, serves as the administration center for the Northern Fleet. There are a large number of naval surface combatants based here, of which two are nuclear-powered. Safonovo, a nearby naval shipyard, is the only local facility that services nuclear-powered submarines.[55]

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51 Ibid., 248.

52 The term "laid-up" refers to the nuclear submarine that has been decommissioned, but that still has its reactors on board. The reactors can be operating or in a storage capacity. The prospect of recommissioning is unlikely. Most Russian nuclear submarines have two reactors.

53 Bradley, 248.

54 Ibid., 248-249.

55 Ibid., 249.

Gremikha, located 280 kilometers east of Murmansk, is the easternmost naval base of the Northern Fleet. Currently there are fifteen laid-up nuclear submarines containing twenty-six fueled reactors awaiting dismantlement. There are also three large radioactive waste storage facilities with major safety concerns similar to those at Andreeva Bay—namely, the lack of efficient and safe arrangements for storage of nuclear materials.[56] Gremikha has become the "bone yard" for decommissioned nuclear-powered submarines, with seventeen to nineteen subs laid-up for dismantlement.

All of the aforementioned naval bases are located on the Barents Sea, although Severmorsk lies well inside the Kola fjord. This is important to note because of the environmental damage that has occurred and is occurring to the Barents Sea, Kara Sea, and Arctic Ocean.[57]

C. ENVIRONMENTAL LAYOUT OF RUSSIAN NAVAL SHIPYARDS

There are six naval shipyards on the Kola Peninsula: Shkul, Safonovo, Sevmorput, and Nerpa located in the Murmansk region, and Sevmash and Zvezdochka located in the Arkangelsk region. The Ministry of Shipbuilding administers Sevmash, Zvezdochka, and Nerpa, whereas the Ministry of Defence administers Shkval, Safonovo, and Sevmorput.[58] There appears to be a disparity in the subordination of these facilities which seems to exacerbate the problems of accountability and responsibility in the dismantlement process.

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56 Ibid., 250.

57 This environmental damage is discussed in Chapter IV of this thesis.

58 Thomas Nilsen, Igor Kudrick and Alexandr Nikitin, "The Russian Northern Fleet Naval Yards," Bellona Foundation 1995. Available [Online]:<http://www.bellona.no/e/russia/nfl/nfl5.htm. [26 September 1999].

1. Shkval

Shkval, located on the western side of the Murmansk fjord near the town of Polyarny (population 70,000), has seven nuclear-powered submarines laid-up. One of those subs, a first-generation Echo II, has a damaged reactor that cannot be touched due to the radiation level in the reactor compartment. Additionally, the radioactive waste storage facilities (two tanks of 150 m^3) are full. Hence, there are two hundred radioactive waste containers and other contaminated material placed in open storage. Shkval faces extensive economic problems, as with all the Russian naval yards.[59]

2. Safonovo

Safonovo is located on the eastern side of the Murmansk fjord between Murmansk and Severomorsk. The SSBNs and nuclear surface combatants are repaired here.

3. Sevmorput

Sevmorput is located on the eastern side of the Murmansk fjord, between the nuclear icebreaker base, Atomflot, and the city of Murmansk (located a few hundred meters away). Sevmorput serviced nuclear-powered submarines from the 1960s until 1991, when officials prohibited nuclear refueling due to radiation safety concerns for the population of Murmansk. Originally, Sevmorput had open air storage for SRW and low-level waste (LLW) in containers, but the theft of three fuel assemblies in November 1993 resulted in all the fuel assemblies being transported to other facilities.[60] One submarine with fuel and one submarine without fuel are laid-up here pending dismantlement.

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59 Ibid.

60 Bradley, 251-252.

4. Nerpa

Nerpa, located a few kilometers west of Polyarny and five kilometers southwest of Murmansk-60 on the Kola fjord, is one of three naval yards responsible for the dismantlement of nuclear-powered submarines. There are generally two submarines in the process of dismantlement, but to date, due to the inability of the Northern Fleet to finance this process, only two nuclear-powered submarines have been dismantled: one Victor I SSN and one Charlie II SSN.

Nerpa has a 500 m^2 (5400 sq.ft.) open air storage facility of SRW approximately 100 meters from the sea. There are 200 m^3 (7000 cu.ft.) of SRW weighing 250 tons in airtight containers. Originally, this waste was collected by Northern Fleet ships and dumped into the Kara Sea. Additionally, there is a 70 m^3 storage tank of LRW.[61]

5. Servodvinsk

The city of Severodvinsk lies on the White Sea thirty-five kilometers west of Arkangelsk. With minor exceptions, Severodvinsk has been a closed city since 1936. The population of over 200,000 grew up around, and in support of, the two largest naval shipyards in the Northern Fleet: Sevmash and Zvezdochka. Both of these facilities were originally designed for the construction and repair of nuclear-powered submarines, but since 1992, they have also served, along with Nerpa, as the main facilities for the decommissioning of nuclear-powered submarines. These facilities currently have twelve to seventeen submarines laid-up awaiting dismantlement and four floating reactors from previous submarine dismantlements awaiting proper long-term storage.

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61 Nilsen et al. 1995.

There are four storage facilities for SRW in Severodvinsk. One is located near the city of Mironova Heights and the other three within the shipyards. Until 1991 most of the SRW in this area was dumped in the Kara Sea. There are over 12,000 m^3 of radioactive waste stored in Severodvinsk, some of which has been stored haphazardly, creating an inherently unsafe environment.[62]

Consequently, the coastline of the entire Kola Peninsula, from the Arctic and Norwegian Seas to the depths of the White Sea, is dotted with Northern Fleet naval bases and naval shipyards. These facilities are home to approximately two-thirds of Russia's nuclear- powered submarines and the associated problems of managing their radioactive waste.

The downward spiral of Russia's economy and political system has created a nuclear "nightmare" in the Northern Fleet. Submarines that were designed to operate for twenty years are being decommissioned early and at an alarming rate. Older first and second-generation submarines are being laid up for years due to the lack of financing and the government's inability to carry out a safe dismantlement process. This situation has resulted in a bottleneck of "dying" nuclear-powered submarines of catastrophic proportions. According to Kostev,

> [T]he Navy does not have enough money for the conservation of ships withdrawn from active service. Under lack of financing, the Navy lacks funds for maintaining combat ships in proper conditions. It means that it [the Navy] is not interested in allocating money in maintaining decommissioning ships reliably conserved. It [the Navy] is not interested as well in investing into preserving [the] ecological situation in areas, where dismantling nuclear powered ships are concentrated.[63]

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62 Bradley, 252-253.

63 Georgi Kostev, *Nuclear Safety Challenges in the Operation and Dismantlement of Russian Nuclear Submarines* (Moscow: Committee for Critical Technologies and Non-Proliferation, 1997), 37.

Concerning the bottleneck problem of decommissioned nuclear-powered submarines, Tatko and Robinson made the following comments:

> Although reports may vary, figures published in March 1998 indicate that the Northern Fleet has forty-seven operational nuclear submarines.... A total of ninety-two Northern Fleet nuclear-powered submarines had been decommissioned by July 1998. Of this total, sixty-five submarines have not been defueled. Only two submarines had been completely dismantled as of fall 1997.[64]

As of July 1999, it is estimated that there are 104 decommissioned submarines laid-up, due to financial and technological problems and a lack of storage facilities, at Northern Fleet naval bases and shipyards, of which seventy-two have not been defueled.[65] According to Tatko and Robinson,

> With the end of the Cold War and the collapse of the Soviet Union.... the Northern Fleet faces a number of problems related to its aging fleet, the naval nuclear fuel cycle, decommissioning and dismantlement demands, radioactive waste and contamination, and the Russian military's severe economic problems.[66]

The conditions of Russia's radioactive waste management, primarily the long-term storage and disposal crisis, will probably continue to deteriorate as long as the bottleneck in the dismantlement process persists and the economic situation worsens.

D. THE DISMANTLEMENT PROCESS

Beginning in the 1980s, first generation Soviet nuclear-powered submarines began being retired and laid-up pending dismantlement. However, no plan to safely carry

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64 Tatko and Robinson, "Northern Fleet Overview".

65 Cristina Chuen, Monterey Institute of International Studies, interview by author, 13 March 2000. The sources cited for this conclusion include: Rocky's Information Service, http://members.xoom.com, Kvaerner Maritime's "Status and Review of the Masterplan for Disposal of Russian Nuclear Submarines," 1 June 1999, *Jane's Fighting Ships 1999/2000*, 5580571, and NISNP discussions with DOD personnel, December 1999.

out the process was ever initiated. Since then, Russia has not decommissioned and/or dismantled a single submarine with the issues of handling and storing nuclear materials satisfactorily resolved. Prior to the 1980s, older nuclear submarines were kept in service until it was no longer feasible to safely operate them, at which point the submarines were either laid-up or dumped in the Kara Sea. In 1993, Russia ceased the latter practice and pledged to abide by the protocols of the London Dumping Convention.

According to Nilsen, Kudrik, and Nikitin, Russian nuclear submarines are currently decommissioned for three reasons.

> Firstly, some of the vessels are more than 25 years old and past their effective service life. Some of them have undergone serious accidents and are beyond repair. Secondly, the greatly reduced Russian defense budget precludes maintenance and upgrading of the large cold war force of nuclear submarines established by the Soviet Union. Thirdly, international disarmament treaties for the reduction of naval nuclear strategic warheads require a reduction in the number of submarines.[67]

Because the Russian government has never given the decommissioning and dismantlement process proper consideration and funding, the process is not simply a Russian national problem, but an international problem.

If one were to create a list of the stages involved in the dismantlement process, it would seem rather simple:

- removal of the submarine from active status
- extraction of the spent nuclear fuel and disconnecting of nuclear reactor circuits
- transport of spent fuel for reprocessing
- containment of the low- and high-level radioactive wastes
- removal of missiles
- dismantlement of the ballistic missile launch tubes (for SSBNs)
- removal and recovery of reusable equipment and metals

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66 Tatko and Robinson, "Northern Fleet Overview." 1.

67 Nilsen et al. 1995.

- separation of the reactor compartment from the rest of the hull
- sealing of the reactor compartment for long term storage
- and scrapping of the remaining parts.[68]

However, the Russian Navy is not prepared to handle the tasks on this list. In fact, "this rapid, simultaneous, grand-scale decommissioning of [nuclear] submarines of multiple generations and classes not only complicates the dismantlement process, but also jeopardizes the environment."[69]

Some Russian officials refer to the decommissioning and dismantlement process as "The Program," and no one in the Russian government wants to take responsibility for it.[70] In 1986, governmental decree number 095-296 outlined the guidelines for the dismantlement process. In July 1992, governmental decree number 514 was ratified, assigning the naval shipyards of Severodvinsk in the Arkangelsk region, Sevmash and Zvezdochka, and Nerpa in the Murmansk region, the jurisdiction of carrying out "The Program." In June 1994, the problems associated with "The Program" were raised by the Duma. The Commission for Emergency Action raised the same problems again in March 1995, but, in both cases, the decrees and the discussion fell on deaf ears. Hence, no submarine to date has been responsibly decommissioned and dismantled, in compliance with the safety regulations. Indeed, some nuclear-powered submarines have been dismantled, but their reactor compartments have been either dumped in the sea or are still

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68 Jill Tatko and Tamara Robinson, "Decommissioning and Dismantlement Overview," Monterey Institute of International Studies, 1998. Available [Online]:<http://www.cns.edu/db/nisprofs/russia/naval/decom/decomovr.htm. [2 October 1999]. 1.

69 Ibid.

70 Kostev, 85.

floating on the sea.[71] Nilsen, Kudrik, and Nikitin make the following points concerning the safe dismantlement process of Russian nuclear-powered submarines:

> According to [Russian] naval yard authorities, safe decommissioning of nuclear submarines will not be possible for another five to seven years. The Russian Ministry of Defence claims that the present economic situation rules out a sustainable rate of decommissioning before 2005-2010.[72]

Spurred by Russia's declining economic conditions in the 1990s, the priority of the Northern Fleet has been to service the operational submarines rather than those in a decommissioned status. "Between 1988-1995, only ten Northern Fleet nuclear-powered submarines have been defueled."[73]

The actual process is actually quite cumbersome, time-consuming, and expensive. Once a vessel has been decommissioned, it is transferred to the appropriate naval shipyard, unless it is laid-up elsewhere for countless years. The hull is then cut into three parts to facilitate the removal of the missile compartment, if applicable. The three parts are then welded back together and the submarine is set afloat pending the removal of its nuclear fuel and reactor compartment. This process cannot be completed until a dismantling slot becomes available in Sevmash, Zvezdochka or Nerpa.[74]

Defueling a nuclear submarine involves the removal of radioactive fuel assemblies from the reactors. The fuel assemblies are then temporarily stored until they are shipped off for reprocessing or long-term storage. Under ideal conditions, the fuel

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71 Nilsen et al.1995.

72 Ibid.

73 Bradley, 290.

74 Ibid., 291.

assemblies would be transported from temporary storage to Murmansk where they would be loaded into special transport containers (TK-18), loaded onto special rail cars (TK-VG-18) and transported to a special chemical processing plant in Mayak. Mayak is located in Siberia, 3,000 kilometers from Murmansk. Murmansk is the only site for the transfer of fuel assemblies because it is the only facility with a central railroad system capable of handling the special rail cars. Fuel assemblies located in Severodvinsk, Gremikha, Andreeva Bay, and other areas outside of Murmansk, are transported by special transport service ships to Murmansk when storage is available. There are plans to build and update the current rail systems in the Sererodvinsk area to establish direct access to Mayak.[75]

Each TK-18 container can house a maximum of forty-nine fuel assemblies and each TK-VG-18 rail car can transport three TK-18 containers. Only four of these special railcars have been placed into service. Hence, a fully loaded train could carry a maximum of 588 fuel assemblies. The typical nuclear-powered submarine has two reactor cores containing between 248 and 252 fuel assemblies each. Each fuel assembly contains several tons of uranium packed fuel rods. Currently, less than four shipments a year are being conducted because the Northern Fleet lacks the funds to pay for the service. To reduce the current burden caused by the storage of nuclear material and to bring it down to a manageable level would require a minimum of ten trips to the Mayak facility.[76]

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75 Bradley, 285-287.

76 Nilsen et al.

After the removal of the fuel assemblies, the primary circuit compartment, including the reactor tank, is separated from the submarine, which is cut up for scrap metal. The reactor compartments are then prepared for long-term storage or disposal.

> After the fuel has been removed from the reactor compartment of a nuclear submarine, about 100,000 Ci of induced radioactivity remains. About 99% of this is in the reactor vessel and adjacent metal structures, with only about 0.1% of the radioactivity accounted for by corrosion products spread through primary coolant circuit surfaces. During the first 50-70 years, essentially all the radioactivity from the radiation standpoint is due to ^{60}Co.[77]

During this step of the process, various types of radioactive waste are generated.

> More than 95% of the contaminated material comes from the reactor, representing approximately 7% of the submarine volume. Usually, most of the LRW is drained from the reactor when the fuel assemblies are removed. The liquid waste from this operation amounts to 200 m^3: 20 m^3 from the primary coolant circuit, 4 m^3 from filters, and 170 m^3 from biological shielding tanks in the reactor compartment. Flushing of the primary reactor cooling circuit produces about 100 m^3 of liquid waste with an activity of up to 10^2 Ci/l.... Long-lived isotopes, ranging from 270 to 27,000 Ci in total, constitute about 90% of the radioactivity in the reactor compartment 3-5 years after the removal of reactor fuel.[78]

There are three ways to prepare the reactor compartment for transport or long-term storage. 1) The submarine may be cut up in such a way as to leave an extra compartment fore and aft of the reactor compartment allowing it to float. 2) Only the reactor compartment may be removed, with pontoons fastened to it, allowing it to float. 3) The reactor compartment may be filled with the buoyant substance polisterol, to keep it afloat.[79]

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77 Bradley, 291.

78 Ibid.

79 Nilsen et al.1995.

Once the reactor compartment is prepared for transport or long-term storage, in Severodvinsk and Nerpa, it is towed to Sayda Bay where it is temporarily stored at various piers until a permanent location can be determined. Thus far, no decisions have been made as to where this facility will be. There has been some planning to use the submarine concealment tunnels at Ara Bay, but this would present extreme risks of radioactive leakage into the sea due to flooding.

The challenges of the decommissioning and dismantlement process are enormous and expensive. There are no quick fixes and little financial support.

E. CHALLENGES TO THE DISMANTLEMENT PROCESS

The Northern Fleet faces serious challenges associated with the decommissioning and dismantlement of nuclear-powered submarines. The challenges stem in large part from Russia's economic crises. These challenges involve financial, planning, and technical factors.[80]

There is an ongoing conflict within the Russian Ministry of Defense regarding the allocation of the defense budget. The Defense Ministry leadership is continually cutting back on the allocations to the Navy. It is through navy funding that the dismantlement process is supported; and a lack of funds for the navy equates to a lack of funds for the dismantlement process. Army Generals, who have little interest in the needs of the Navy, have traditionally held the dominant leadership positions within the Ministry of Defense. Little has changed with the transition of Soviet Russia to Russia. If anything, the

[80] Jill Tatko and Tamara Robinson, "Naval Nuclear Vessels Overview".

situation has worsened due to the economic struggles of the dominant nuclear branches, the Navy and the Strategic Rocket Forces (SRF).[81]

Russia's SSBN force faces a grave dilemma. The Russian Navy is unable to properly maintain and secure its nuclear-powered submarine force, and the Russian military plans to transfer fifty percent of its strategic missiles to nuclear-powered submarines in late 2000. As it stands, three of the six strategic ballistic missile submarines, Typhoon class SSBNs, are in the poorest condition and incapable of remaining combat-ready due to a lack of funding. The other SSBN classes, Delta III and Delta IV, are experiencing similar difficulties.

> There are a number of reasons behind the lack of funds which are needed for repairing [and maintaining] operational strategic missile-carrying submarine cruisers and constructing new ones. Namely, it's stated that investments of capital in the naval component of Russia's strategic nuclear forces are three times less effective than those made in ground-based missile complexes.[82]

There are three aggravating factors to this situation. First, the shipbuilding industries, which have significant influence with government authorities, are securing contracts for new construction, to the detriment of the ship repairing industry, which is responsible for repair and dismantlement. Second, the navy has little choice but to allocate the major portion of its budget to maintain operational vessels instead of spending funds on those destined for dismantlement. Third, navy and civilian personnel are not being paid for months at a time. This has led to incidents ranging from civilians

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81 Kostev, 107.

82 Ibid., 108.

blocking access to naval facilities to naval officers stealing radioactive material from decommissioned nuclear-powered submarines.[83]

By the end of 1998, it is estimated, only $500 million of the required $2.2 billion ($1.4 billion for the Northern Fleet) had been allocated for the dismantlement process, including fuel and waste storage and transportation.[84] This price tag will grow exponentially as the cost of maintaining one decommissioned nuclear-powered submarine is approximately $200,000 per year, including a partial crew to oversee general maintenance and reactor operation. This equates to $26 million per year for 130 submarines and does not include the costs of any environmental damage owing to inadequate radioactive waste storage.[85]

The explanation for the lack of planning begins with the ambiguity over which agency has jurisdiction and responsibility for the dismantlement process. Additionally, no plan for addressing the dismantlement of nuclear-powered submarines existed until 1986.

> As a consequence, the agencies involved in the naval fuel cycle, radioactive waste handling and dismantlement are left without a cohesive and organized plan for the oversight of the dismantlement process. Responsibility for the decommissioning and dismantlement of nuclear-powered submarines falls in the hands of many agencies, including the Russian Navy, the Ministry of Atomic Energy, the Ministry of Defense, the Ministry of Finance, the Ministry of Environmental Protection and Gosatomnadzor [the Russian Federal Inspectorate for Nuclear and Radiation Safety]. These agencies experience problems of coordination,

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83 Nilsen et al. 1995.

84 Tamara C. Robinson, "Submarine Dismantlement and Material Storage Challenges for Russian Nuclear Propulsion," 9.

85 Tamara C. Robinson, "Submarine Dismantlement and Material Storage Challenges for Russian Nuclear Propulsion," 9.

competition for control and for funds, and conflicts about interpreting the guidelines. In addition, ongoing military reform and complicated military engagements...distract the Russian military from tackling environmental problems and only exacerbate the complications of decommissioning and dismantlement.[86]

Beginning in 1992, the Russian Navy had big plans to deal with the technical deficiencies concerning the decommissioning and dismantlement process, but nothing happened. According to Moltz and Robinson, the four major technical obstacles facing the Russian dismantlement process are:

> 1) inadequate spent storage and transport capabilities; 2) problems with liquid radioactive waste storage and filtration; 3) the slow work pace of existing dismantlement lines; 4) the lack of facilities for the long-term storage of highly radioactive reactor compartments. The most serious obstacle Russia now faces is its inadequate storage and transport capabilities for submarine fuel.[87]

For example, Andreeva Bay, the largest radioactive waste storage facility in the Northern Fleet, is reported to have in excess of 21,000 spent fuel rods.

Although Kostev recognizes these technical obstacles, he would argue that the real challenges facing Russia in this regard are as follows:

> Protecting the crew and other people from radiation exposure in the process in [of] removing nuclear-powered submarines from the Navy, making sure that these ships keep afloat and preventing reactor accidents constitute the most acute, difficult and important task which the Russian Navy is facing today.[88]

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86 Jill Tatko and Tamara Robinson, "Decommissioning and Dismantlement Overview" 3.

87 James Clay Moltz and Tamara Robinson, "Dismantling Russia's Nuclear Subs: New Challenges to Non-Proliferation," *Arms Control Today*, June 1999. 12.

88 Kostev, 50.

F. CONCLUSION

The last forty years turned the Northern Fleet geographical area into a potential nuclear wasteland. During the Cold War, Soviet Russia built 245 nuclear-powered submarines. Post-Soviet Russia can not afford to maintain all these submarines. Moscow must now contend with this Cold War "fallout." Currently, ninety-six nuclear-powered submarines have been decommissioned. Of these ninety-six, seventy-eight have yet to be defueled.

Russia acknowledges the political and environmental implications of the decommissioning and dismantlement process, but the current Russian economic crisis precludes it from doing little more then acknowledging the problem. Historically, Russia was able to dispose of its radioactive waste, spent nuclear fuel, and reactor cores by dumping them into the Barents Sea, the Kara Sea, and/or in coastal and land-based areas of the island of Novaya Zemlya. Consequently, all Russian nuclear storage facilities are full, and Russia is maintaining radioactive material in open-air storage. Although a "Chernobyl-like" incident could not occur with a single naval reactor, the piling up of spent nuclear fuel and radioactive waste could trigger an uncontrolled chain reaction resulting in a nuclear explosion.[89]

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[89] Kostev, 67-68.

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IV. ENVIRONMENTAL AND NON-PROLIFERATION RISKS

A. INTRODUCTION

With Russia's emergence as an independent state, following the collapse of the USSR in 1991, came the public revelation of the nuclear risks associated with its policies and circumstances. The environmental and proliferation risks are particularly noteworthy. Soviet and Russian nuclear practices have produced hazards that are causing environmental damage to Russia and that could cause radioactive contamination and environmental damage to neighboring countries, as well as the Barents Sea, the Arctic Sea, the Kara Sea, the White Sea, and the Arctic Ocean.[90] Additionally, current Russian arrangements may provide an environment conducive to nuclear proliferation.

As Russia's economy continues to falter, these nuclear issues have become a great concern for its neighbors in the northern hemisphere. Indeed, the nuclear waste management crisis in the Northern Fleet has presented the Russian government with a dilemma that requires immediate answers and demands immediate action.

> Is it possible for the Russian Government to provide financial resources to secure nuclear waste in the remote areas in the far North, when even some high-ranking admirals claim they cannot guarantee a reliable early warning system for Russia's strategic forces? And will it be possible for the international community to provide financial and technical assistance to secure nuclear waste in Russia when Western experts are not allowed to inspect the "secret" nuclear waste storage facilities?[91]

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90 Thomas Nilsen, Igor Kudrick and Alexandr Nikitin, "The Russian Northern Fleet: Sources of Radioactive Contamination," Bellona Foundation 1995. Available [Online]:<http://www.bellona.no /e/russia /nikitin /981016_thn.htm. [09 November 1999].

91 Nilsen et al. 1995.

The Northern Fleet's submarine nuclear reactors generate a major source of the radioactive waste on the Kola Peninsula. In an attempt to manage this problem, the Northern Fleet utilizes six naval bases for storing solid and liquid radioactive wastes (SRW and LRW) and two bases with the facilities to store spent fuel assemblies. The Northern Fleet also employs technical service ships that have the capability of storing spent fuel assemblies, LRW and SRW. Additionally, the Kola Peninsula shipyards store considerable amounts of radioactive waste.[92] Soviet and Russian practices in the management of radioactive waste have led to a nearly irreversible pattern of environmental damage and the potential for a radioactive catastrophe.

The methods of storing radioactive waste in land-based storage facilities in the Northern Fleet have changed very little since the emergence of Russia in 1991. These methods and related practices are discussed in this chapter. One of the most significant Soviet practices was dumping radioactive waste at sea.

B. HISTORICAL PRACTICES

The Soviet Union began dumping radioactive waste in northern seas beginning with its first nuclear-powered submarine in 1959. The dumped waste originated from the operation and maintenance of nuclear-powered submarines, as well as civilian nuclear icebreakers. Russia, Soviet and post-Soviet, has dumped twice as much radioactive waste at sea as the twelve other nations that dump at sea combined. Soviet and Russian dumping has been done in shallow waters, north of the 50th latitude, and on the continental shelf.[93]

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92 Bradley, 241-242.

93 Nilsen et al. 1995.

Since 1960, the Northern Fleet has consistently dumped radioactive waste into the Barents Sea and the Kara Sea. This has included solid and liquid radioactive waste as well as nuclear reactors, with and without fuel.[94] According to Nilsen, "In all, Russia (former Soviet Union) has dumped between 115,000 TBq (3.1 million Ci) and 333,000 TBq (9 million Ci) at sea. In comparison, all other countries put together have dumped 46,000 TBq (1.24 million Ci) during the period of 1946 – 1982."[95]

Since 1959, the liquid radioactive waste (LRW) dumped at sea has been a product of cooling water from submarine reactors and fuel assembly storage tanks. The last documented dumping of LRW occurred in November 1991; but this practice may be continuing, because no practical alternative methods of storage or disposal exist.

> According to regulations set forth by the Soviet Navy in 1968, the liquid radioactive waste should have a maximal concentration of radioactivity of 370 Bq/l of long-life radioactive isotopes, and 1850 kBq/l of short-life isotopes. Whether these regulations are observed, is not known.[96]

The highest concentrations of dumped LRW are located in three dumping fields in the northern portion of the Barents Sea, west of the island of Novaya Zemlya, while low-to-intermediate concentration levels of LRW have been identified off the shores of the Kola Peninsula.[97]

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94 Ibid.

95 Ibid.

96 Ibid.

97 Ibid.

> From 1959 up to 1991, 3.7 Tbq (100 Ci) liquid radioactive waste has been dumped in the White Sea, 451 Tbq (12,171 Ci) in the Barents Sea, and 315 Tbq (8,500 Ci) in the Kara Sea. 430 Tbq (11,600 Ci) radioactive water has leaked out in the sea following accidents concerning storage of fuel assemblies, submarines, and the civil nuclear icebreaker *Lenin*. The radioactivity of the liquid waste dumped in the Barents Sea, Kara Sea, and White Sea totals 880 Tbq (23,771 Ci).[98]

Since 1965, solid radioactive waste generated by the Northern Fleet, in containers and without containers, has been dumped in eight different bays off the eastern coast of Novaya Zemlya and in the Kara Sea. Additionally, the Northern Fleet has sunk seventeen ships containing various types of radioactive waste of various levels of radioactivity in the Barents Sea and Kara Sea. Before these ships were sunk, the navy placed contaminated parts from submarine reactors, equipment used on the reactors, reactor sections, reactor cooling water pumps, reactor generators, and varying metal parts in them.[99]

According to Nilsen, Kudrick, and Nikitin,

> a total of 6,508 containers of radioactive waste has been dumped directly in the Kara Sea. The Northern Fleet has dumped 4,641 of these. In archives of the Murmansk Shipping Company, dumping of 11,090 containers into the sea has been recorded. This implies the company has dumped 1,867 individual containers, while the remaining 9,223 containers were placed aboard lighters and ships before they were sunk.[100]

The radioactive waste containers hold from 0.5 to 1 m^3 of radioactive waste, and are made of plain iron, with some lined with concrete.[101] During the 1960's, many of the

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98 Ibid.

99 Nilsen et al.1995.

100 Ibid.

101 Bradley, 293.

dumped radioactive containers did not sink. Disposal crews machine-gunned the containers until they filled with water and sank, but not all their attempts were successful. Hence, there were numerous reports of floating waste containers in the Kara Sea and one report of a waste container found ashore. Placing rocks in the waste containers, along with the radioactive waste, to ensure that they would sink solved this problem. The majority of these incidents took place off the southeastern coast of Novaya Zemlya, in the Ambrosimov Bay.[102]

Thirteen nuclear submarine reactors have been dumped in the Kara Sea, six of which had used nuclear fuel onboard. All these reactors were so badly damaged from serious accidents that the nuclear fuel was impossible to remove, due to the strong radiation. The threat of radiation damage prevented the removal of nuclear fuel before the reactor was dumped. In addition, three nuclear reactors from the icebreaker *Lenin* have been dumped. Some of these reactors had been in storage for less than a year when dumped, while others had been in storage for nearly fifteen years before they were dumped. Russian reactor engineers allege that five of the reactors were filled with a protective sealant of steel, cement, and polyester to prevent radioactive seep. These containers should last for up to 500 years.[103]

America's Lawrence Livermore National Laboratory has estimated the radioactivity released by the three dumped *Lenin* reactors and the submarine reactors dumped with used fuel to be in the vicinity of 178 Pbq (4,800 Ci), and the remaining submarine reactors to be approximately 3.7 Pbq (100 Ci) per reactor. Russian officials

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[102] Nilsen et al. 1995.

[103] Ibid.

calculate the release of radioactivity to be significantly lower—that is, a combined total 85 Pbq (2,300 kCi) for all the reactors.[104]

In 1992, the first of three Norwegian/Russian cooperative expeditions was launched to assess the measurements of radioactivity at the dump sites in the Kara Sea. The results were negligible, as the measurements were taken at locations distant from the actual dump sites. In 1993, the second expedition was granted permission to take measurements at actual dump site fjords, but was denied access to Ambrosimov Bay and Stepovov Bay, the largest solid radioactive waste dump sites. The third expedition in 1994 was finally allowed to visit the Ambrosimov and Stepovov Bays. The expedition through these bays showed that barrels of low-level waste and intermediate-level waste were in "very bad shape," while the containers and submarine reactor compartments appeared to be intact. The Norwegian expedition leader, Lars Foyn, noted that there was almost no biological life in the fjords of Novaya Zemlya.[105]

In Stepovov Bay, the expedition located radioactive waste dump sites that had never been reported. Photographs were taken of sunken barrels, containers, reactor compartments, and submarines. These items were in such poor condition that the remote-control radiation measuring device went through the rusty metal walls.[106]

In Ambrosimov Bay, the expedition was able to locate the following:

Barrels of low- and intermediate-level waste

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[104] Estimate by Lawrence Livermore National Laboratory quoted in Nilsen et al. 1995.

[105] Bradley, 296.

[106] Ibid.

- Three barges full of liquid waste with large receptacles on the deck
- Several large cylindrical container receptacles on one of the barges
- Submarines
- Reactor compartments (with and without fuel).

Other observations were noted as follows:

- Current contamination in the fjords is mostly caused by leaching from the containers; that from reactor compartments was small in comparison.
- Waste containers, submarine reactor compartments, and sunken barges were observed. The container walls were highly corroded and had holes in them.
- Not all of the solid waste types and locations as noted [in official documents] were able to be located, and several of the locations were imprecise.
- The highest activity noted was 60,000 Bq/kg (1.62 mCi/MT), in Stepovov Fjord.[107]

Subsequent expeditions have been made to various dump sites in the Barents Sea and the Kara Sea to test the level of radioactivity, but as of 2000 the results had apparently not been published.

In 1972, the Soviet Union signed the London Convention, limiting the dumping of radioactive waste at sea by ships. The Soviet Union ratified the London Convention in 1975, but continued the dumping of LRW and SRW. The USSR also dumped nuclear submarine reactors containing fuel in the Kara Sea in 1981 and 1988.[108] "Although the Navy stopped dumping LRW in the northern seas in 1986, large amounts of waste remain stored on vessels specially designed for dumping at sea."[109] In July 1988, Soviet authorities claimed that Soviet law prohibited dumping radioactive waste at sea. Additionally, Moscow claimed that the Soviet Union had never dumped radioactive

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107 Bradley, 296.

108 Nilsen et al.1995.

109 Jill Tatko and Tamara Robinson, "Northern Fleet Overview."

waste at sea. Less than a month later, the Northern Fleet dumped two submarine reactors containing fuel in the Kara Sea.[110] According to Georgi Kostev, Soviet-style practices have continued:

> At the present moment the Russian Navy is not ready to discontinue sea dumping of liquid radioactive waste, for the coastal reprocessing enterprises have not yet been brought into operation. It happened because the fleets do not have regional schemes of radioactive waste disposal which would envisage special technological operations with radioactive waste, from the moment of producing till the moment of burying it.[111]

C. CURRENT PRACTICES

Russia's radioactive waste management practices and doctrines are similar to those of the Soviet Union. Although nuclear waste dumping at sea may have tapered off or even ceased in some areas, inadequate nuclear waste storage practices continue. The nuclear submarine dismantlement process has exacerbated the situation. Although other variables contribute to Russia's inability to improve the nuclear submarine dismantlement process, arrangements for storing nuclear waste safely and efficiently are nearly nonexistent.

Although the Northern Fleet utilizes six bases and two shipyards for the storage of its liquid and solid radioactive waste, all of which have serious shortcomings, this chapter concentrates on the crisis at Andreeva Bay. Almost all of the other storage facilities face similar crises, to a lesser or greater degree.

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110 Nilsen et al. 1995.

111 Kostev, 101.

Located on the Kola Peninsula, 45 miles from the Norwegian border, Andreeva Bay is the Northern Fleet's main storage facility for nuclear waste. The base is the only Northern Fleet facility for the storage of spent nuclear fuel from nuclear submarines.

Andreeva Bay houses over 21,000 spent fuel elements, stored in three concrete tanks of poor condition. Since 1990, these tanks have been filled to capacity. Hence, open-air storage has been utilized. To relieve the crowded situation at Andreeva Bay, spent nuclear fuel was shipped to the Mayak reprocessing facility until 1996. In 1997, this transportation ceased completely.[112] However, at least five trains made the trip from Murmansk to Mayak in 1999 and the first train of 2000 arrived on 4 January.[113] During 1997, all the nuclear waste containers shipped to Andreeva Bay from the various dismantlement facilities were stored outside, in open fields, without any protection. Each container holds approximately 35 spent fuel elements with an enrichment of 40 percent. These containers are unsecured, in violation of international as well as Russian regulations for the handling of nuclear waste.[114] According to Georgi Kostev,

> Monitoring the process of fissionable materials piling up is another pressing problem, which is probably the most important one. This is especially true of spent fuel and radioactive waste. Storing them in bulk without any control, piling up of their quantity and mass could result in the most dreadful disaster — in [the] triggering of an uncontrolled chain reaction, in other words, a nuclear explosion.[115]

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112 Nilsen et al. 1995.

113 Chuen, Monterey Institute of International Studies, interview by author, 13 March 2000.

114 Nilsen et al.1995.

115 Kostev, 67.

The solid radioactive waste at Andreeva Bay is stored less than 200 m from the sea, with 50 percent in concrete bunkers and the rest in an open air array outside the bunker. The liquid radioactive waste is stored in five underground tanks of $400m^3$ each.[116]

Building 5, the first storage facility of its kind, is located at Andreeva Bay. Building 5 houses spent nuclear fuel and constitutes a significant example of the crisis facing the Kola Peninsula. Built in 1962 and expanded in 1973, building 5 consists of two rectangular pools, made of concrete and lined with steel plates. These pools are 60 m long, 3 m wide, and 6 m deep with a volume of nearly 1,000 m^3. They were originally designed to house 550 containers of nuclear material, but in 1973 that capacity increased to 2,550 containers. That corresponds to enough fuel assemblies for 50 to 76 nuclear reactors.[117]

The earliest documented problem with this facility occurred in February 1982, when water penetrated the stored containers and thereby facilitated the release of radioactivity. By April 1982, it was assessed that water was leaking at a rate of 100 liters a day, with radioactivity of .0003 Ci/l. By September 1982, the leak seepage was assessed at 30 metric tons of water per day. As work was being performed on the first pool, another leak developed in the second pool; and this resulted in seepage at a rate of 10 metric tons per day. In February 1983, building 5 was deemed unusable. It is estimated that approximately 3,000 m^3 of water with radioactivity of nearly 3,000 Ci leaked from both storage pools. Today building 5 is inoperative and in disrepair. There

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[116] Bradley, 245.

[117] Ibid.

has been no attempt to clean up the building and the equipment it contains due to the gamma radiation rates of 40 R/hr.[118]

The containers that were removed because of the leak were stored in three of the tanks designed for LRW. Since 1995, these tanks have been full. Since 1984, there have been plans for new storage facilities at Andreeva Bay, but none of these plans has been implemented.[119] The dismantlement cannot continue without proper storage for spent fuel assemblies.

The open-air storage arrangement at Andreeva Bay originally consisted of 52 containers of spent fuel assemblies. 20 have been sent to the Mayak facility over the years, but 32 containers with nearly 220 fuel assemblies remain. These 32 containers have been in place and exposed to the elements since 1962. Hence, the containers are corroded and cracked; and water is making contact with fuel elements. Under these conditions, the containers cannot be handled or moved for reprocessing.[120]

Despite these conditions, other facilities throughout the Kola Peninsula, experiencing the same difficulties with the dismantlement process and limited nuclear waste storage, are sending their excess radioactive waste materials to Andreeva Bay.

Given the existing conditions among Russia's Northern Fleet facilities, one must consider the potential for a nuclear catastrophe. While there is considerable risk of further environmental damage at these storage facilities, the greater risk of a nuclear

118 Bradley, 246.

119 Bradley, 247.

120 Bradley, 247.

accident lies with the decommissioned nuclear submarines awaiting dismantlement. According to Kostev,

> about 150 written-off submarines will have to be utilized within the stated period. This implies that the number of poorly controlled sources of radioactivity and the amount of radioactive waste will grow, and the risk of environmental pollution in the regions where decommissioned nuclear-powered submarines are stored will also increase.[121]

Kostev's observation raises the key question at issue in this thesis: Are the variables in place that could lead to another "Chernobyl"?

D. THE POTENTIAL

It is difficult for outsiders to assess the potential for a Russian nuclear submarine reactor disaster, because the detailed design of Russian naval reactors is classified. Hence, the estimates of the destructive consequences of a critical accident discussed in this thesis are largely based on assumptions. To qualify and validate these assumptions, available information about the reactor from the nuclear icebreaker *Sevmorput* is utilized. This reactor presumably has characteristics similar to those of a Russian naval reactor. Like almost all of Russia's nuclear-powered submarine reactors, the *Sevmorput's* reactor is water-pressurized.[122]

The technical condition of submarines awaiting dismantlement is steadily deteriorating. The Russians have taken numerous temporary safety measures to keep the submarines from sinking. These measures include "constant pumping of compressed air

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[121] Kostev, 124.

[122] NATO, *Environmental Risk Assessment for Two Defence-Related Problems: Non-Defueled, Decommissioned Nuclear Submarines*. Report No. 227, March 1998. 66.

into the hulls, welding of bottom seacocks and periodic docking."[123] These efforts are intended to minimize the possibility of a spontaneous chain reaction in the **reactor's** nuclear fuel due to contact with seawater. However, these measures do not eliminate the risks of radioactive leaks. Additionally, if the reactor coolant freezes during the winter, this may cause damage to the fuel assemblies, and thereby increase the risk of an accident when the assemblies are later removed.[124]

> The safety measures that have been applied hardly include monitoring the condition of the nuclear fuel in the reactor. Hence, it cannot be discounted that accidents or leaks of radioactivity could occur.... The reactors themselves [in submarines awaiting dismantlement] are in markedly worse condition than those on operational vessels, for there is more humidity and variations in the temperature as well as the risk of seawater entering the hull.[125]

A constant concern with nuclear submarines awaiting dismantlement is the different supplies of power used for maintaining the various reactors. For example, first generation submarines use either batteries or diesel power, and both produce direct current (DC). Conversely, second-generation submarines use turbo generators of alternating current (AC), and batteries and diesel power as an auxiliary power supply.[126] This approach could lead to a problem as the main control panel of the reactor plant is usually removed upon decommissioning[127] and the partial crew is usually not well trained.

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[123] Nilsen et al. 1995.

[124] Nilsen et al.1995.

[125] Nilsen et al. 1995.

[126] NATO, 21-22.

[127] Ibid., 27.

> The crewmembers often lack the necessary training or are assigned to a laid-up submarine either because they are lacking in competence or are unfit to serve on an active vessel. Thus the lack of competent, qualified personnel increases the possibility of emergency procedures not being executed correctly in the event of a serious incident.[128]

Under ideal conditions, the internal events that could result in a critical accident are generally not a concern in decommissioned submarines. If, however, one of these events occurs, especially loss-of-coolant, flooding or sinking, a release of radioactivity will probably follow. Internal events are categorized as follows:

- Critical accidents
- Primary heat transport system failure
  - Loss-of-coolant events
  - Loss-of-coolant flow events
  - Fuel channel blockage
- Secondary heat transport system failure
- Cooling-water system failure
- Electric system failure
- Instrument air system failures
- Hydraulic oil system failures
- Flooding
  - Fires and explosions
  - Sinking[129]

The Kurchhatov Institute report considers the probabilities and consequences of three other types of dangerous accidents:

- Overheating of fuel elements due to a lack of cooling caused by an accidental loss of coolant in the primary circuit of the reactor.

- Spontaneous chain reaction (SCR or criticality) in a nuclear core of the reactor due to an unauthorized manipulation of the reactor control mechanisms or due to personnel mistakes or equipment malfunctions during spent nuclear fuel (SNF) removal from the reactor.

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[128] Nilsen et al. 1995.

[129] NATO, 42.

- Accidental sinking of a nuclear submarine with spent nuclear fuel onboard.[130]

It must be emphasized that these events are generally not a concern for decommissioned submarines as long as rules and regulations are followed.[131] But, as noted above, the crews manning these submarines are not all that competent, and they are coping with poor economic and social conditions.

The greatest potential for a critical accident resides in an external event, a spontaneous chain reaction during reactor defueling of a decommissioned submarine. As previously mentioned, there are 110 to 115 decommissioned submarines, with fuel still onboard, awaiting dismantlement. According to the Kurchatov Institute,

> [The] Northern Fleet needs to fulfill 44 such defueling operations with FG [First Generation] submarines. The product of assessed SCR [spontaneous chain reaction] probability by expected number of defuelings is about 0.1. This total probability of SCR accident looks too high.[132]

Considering all the various problems that have been identified with the Northern Fleet, what would a nuclear accident imply? The "worst case" scenario must be considered. This scenario would probably involve a severe defuelling accident with one of the decommissioned submarines.

A severe defuelling accident could give rise to a steam explosion, followed by a release of radioactivity into the atmosphere. The heat of this explosion would cause a radioactive plume to rise, and the height of the plume and other factors (such as weather)

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130 V.S Ustinov, A.P. Zotov et al., "Nuclear Safety Assessment of Stored Afloat Non-Defuelled Decommissioned Nuclear Submarines" [Final Report], Kurchatov Institute, Moscow, July 1997. 20.

131 NATO, 27.

132 V.S Ustinov, A.P. Zotov et al., 20.

would determine how extensive the radioactive release would be. The probable height of this type of accident is assessed to be 50 to 100 m. The Chernobyl accident's plume ranged between 200 and 1200 m, but this was greatly enhanced by the persistent graphite fire.[133]

The radioactive elements released by this accident would probably be similar to those at Chernobyl, including ^{137}Cs, ^{90}Sr, and ^{239}Pu. The distance these pollutants would travel would depend on the characteristics of the plume, the wind, and the weather.[134] It should be noted that the possible accumulation of radioactive nuclides from the fuel in a nuclear submarine reactor might be 10 to 20 times less than that at Chernobyl, primarily because the increased temperature of a submarine reactor would probably last only a short time.[135]

In the model used by the NATO pilot study to evaluate the probabilities involved in a severe nuclear accident, the accident would hypothetically occur at Ara Bay. Two approaches using "real-time" calculations were evaluated, the probabilistic approach and the "plausible worst-case" approach.[136]

The probabilistic approach suggests that 80 percent of the released radioactivity would fall on Russian territory and/or in the Barents Sea. This would affect almost all of

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133 NATO, 81.

134 Ibid., 80-81.

135 V.S Ustinov, A.P. Zotov et al., 32.

136 NATO, 82-83.

the population on the Kola Peninsula. The remaining 20 percent would likely drift toward the Norwegian border.[137]

The "plausible worst-case" approach suggests that the majority of the released radioactivity would head towards Norway, Finland, and Sweden. The level of precipitation would have an extreme effect, a factor of 100 to 1000 times, on the amount of deposited contamination. This could create hot spots in the plume's track.[138]

> As a result, rainfall during cloud passage may lead to contamination rates comparable to the situation in the middle of Sweden following the Chernobyl accident, but the affected area will be much smaller.[139]

It should be noted, especially in the Nordic area, that the actual radioactive dose rate would be dependent on the seasonal effects at the time of the accident, such as snow cover and the grazing of animals. The NATO study assessed that 30 percent of the local food products would be contaminated.[140]

One must keep in mind that the scenario above would result from one reactor accident, while there are over 100 submarine reactors awaiting dismantlement. Additionally, consideration must be given, in the scenarios posited in both approaches, to the environmental and health consequences discussed in Chapter II.

E. CONCLUSION

Moscow's practices, during the Soviet period and subsequently, have presented Russia and the rest of the world with a serious dilemma. Russia's insufficient ability to

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137 Ibid.

138 Ibid., 84.

139 Ibid.

140 Ibid., 85.

safely store nuclear waste and effectively process spent nuclear fuel assemblies has created a bottleneck of decommissioned nuclear-powered submarines awaiting dismantlement. This situation has furnished the basis for nuclear accidents which could inflict serious environmental damage. According to a NATO study,

> The handling of decommissioned submarines in general and the defuelling of their reactors in particular are difficult and potentially dangerous tasks that require well-defined rules and procedures as well as well-educated and motivated personnel. Accidents and incidents that have taken place over the years have led to some concern about the current adherence to safety standards and the safety culture among the personnel who perform these tasks. A deeply embedded safety culture is crucial to the successful decommissioning of nuclear submarines.[141]

With the political and economic conditions in Russia, there is probably no way for the Russian government to effectively deal with the dismantlement crisis without the aid and support of foreign governments and organizations. These entities cannot, however, begin to formalize the necessary aid packages until the Russian government lowers its cloak of secrecy and allows participating governments and agencies to assess the situation. This crisis was exacerbated in July 1999 when Vladimir Putin, then head of the FSB, the domestic security agency that succeeded the Soviet-era KGB, declared that environmental organizations are being used as fronts for Western spy agencies. Mr. Putin stated that "environmentalists will always be the focus of our attention."[142]

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141 NATO, 90.

142 Putin quoted in Dan Gardner, "Environmentalists denounced as western spies," *Ottawa Citizen*, 24 July 1999. 2.

F. PROLIFERATION RISKS

The Northern Fleet's situation could also increase proliferation risks. The underlying shortcomings of the Russian nuclear submarine dismantlement process could fuel a proliferation crisis. Three proliferation risks are particularly noteworthy: diversion, terrorism, and capitalism.

The theft or diversion of naval reactor fuel is probably the most serious of the three risks. There are at least two documented cases of nuclear fuel theft in the Northern Fleet and numerous other reports in the Pacific Fleet.

In July 1993, "a guard and a sailor absconded with 1.8 kg of 36% HEU (two fresh fuel rods) from Andreeva Bay, a fuel and radioactive waste storage site located at Zapadnaya Lista Naval Base near Murmansk."[143] The two individuals were apprehended, with the fuel rods, by Russian security officers a short distance from the base. The guard and the sailor were subsequently sentenced to prison for four and five years respectively. This imprisonment was ordered despite claims that they were following orders from two senior naval officers.[144]

In November 1993, two naval officers diverted 4.5 kg of 20 percent HEU (equivalent to three fresh fuel rods), at the Sevmorput shipyard, located near Murmansk. The theft was discovered only because a door to the storage facility was left open.

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143 James Clay Moltz and Tamara C. Robinson, "Dangerous Delays in Russian Nuclear Submarine Dismantlement," Monterey Institute of International Studies, 1999. 4.

144 Ibid.

"Authorities arrested the two officers after a brother of one of the perpetrators, also an officer at Sevmorput, started asking around for potential buyers."[145]

Since 1994, four additional cases of theft or diversion have been reported, but the outcomes of these cases remain unclear. Additionally, Gosatomnadzor [the Russian Federal Inspectorate for Nuclear and Radiation Safety] reports at least nine cases of discrepancies between the listed inventory of nuclear fuel and the actual amount of fuel at the storage sites. Although an additional step in reprocessing is required to make weapons grade plutonium out of spent fuel, there are serious concerns about the lapses in nuclear material protection, control, and accounting (MPC&A). Currently, Russia has no central MPC&A system.[146]

> These cases suggest a considerable black market interest in naval fuel. Several of the incidents are consistent with the "insider theory", which posits that facility personnel are just as likely, if not more likely, to be the perpetrators of diversions as outsiders. They know where the material is stored, what kinds of physical protection measures are in place, and how to get around them.[147]

Terrorism, on the other hand, is indifferent to the insider or the outsider. A terrorist could board a poorly guarded decommissioned submarine. Physical protection of these vessels is difficult. One of the perimeters is water, and personnel shortages have reduced the number of guards protecting some of these vessels to one. These circumstances increase the terrorist opportunity for attack.[148]

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145 Ibid., 5.

146 Moltz and Robinson, "Dangerous Delays in Russian Nuclear Submarine Dismantlement," 5.

147 Ibid., 6.

148 Ibid., 7.

One particular incident demonstrates Russia's vulnerability to an "insider" terrorist attack. In September 1998,

> A young Russian sailor commandeered an active duty Akula-class SSN that was docked at the Gadzhiyevo Naval Base, killing eight of his colleagues in the process. He barricaded himself in the submarine's torpedo room, where he was preparing to set fire to the submarine and detonate its torpedoes.... When Federal Security Forces (FSB) troops stormed the torpedo compartment, they found the assailant dead, evidently from a smaller accidental explosion while preparing the torpedo "bonfire."[149]

Had the sailor been successful, adjacent submarines might have also been destroyed, releasing ever greater amounts of dangerous nuclear material into the atmosphere and the water.[150]

If this type of incident is possible on an active duty nuclear submarine, the potential for a terrorist attack at poorly guarded and poorly protected nuclear waste storage facilities and on decommissioned submarines with fuel on board must be significantly greater.

Finally, there is capitalism. If the Russian government lacks the ability to make progress in dismantling decommissioned submarines and economically cannot afford to provide adequate protection and storage for these submarines and their associated materials, why not sell them rather than scrap them? In fact, there is Russian interest in this option.

In 1999, India expressed interest in purchasing decommissioned nuclear submarines, as they were considerably cheaper than incomplete new submarines.

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149 Moltz and Robinson, "Dangerous Delays in Russian Nuclear Submarine Dismantlement," 7.

150 Ibid., 8.

This interest began in the 1980s, when India leased a Russian nuclear submarine for two years.[151]

> Sales of second-hand [nuclear submarine] vessels could set the stage for possible transfer to other interested parties, such as India's rival Pakistan, North Korea, South Korea, and possibly states in the Middle East.[152]

The revenue from submarine sales and ship repair contracts and the relief in the dismantlement process might furnish incentives for the Russian government to reactivate and sell these vessels. "Under a loophole in the Treaty on the Non-Proliferation of Nuclear Weapons (NPT), Russia could provide HEU fuel for these submarines outside of the IAEA safeguards."[153] As Moltz and Robinson point out,

> The threat of dozens of cut-rate Russian submarines cruising the world's oceans under other flags is an unsettling one for military, proliferation-related, and environmental reasons.[154]

Although Russian determination and exports might resolve a fraction of the nuclear submarine dismantlement problem, significant external assistance will be necessary to address the problem sufficiently.

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151 Moltz and Robinson, "Dangerous Delays in Russian Nuclear Submarine Dismantlement," 9.

152 Ibid.

153 Ibid., 9-10.

154 Ibid., 9.

V. EXTERNAL ASSISTANCE TO RUSSIAN DISMANTLEMENT EFFORTS

A. INTRODUCTION

The estimated cost of Russia's nuclear submarine dismantlement program, for the Northern Fleet alone, is approaching two billion dollars. The Russian government, however, has only provided a quarter of that sum. By the end of 1998, an estimated $500 million had been allocated.[155]

Foreign assistance totaled nearly $30 million in 1998, and was expected to increase to $50 to $60 million in 1999. (Precise information on current foreign assistance is not available at this writing.) But the average cost of dismantling one Russian nuclear submarine runs from about $7 million to $10 million. The sale of scrap metal from the submarine recoups only 20 percent to 30 percent of the dismantlement costs.[156] According to Moltz and Robinson, the goal of the Russian government is the elimination of all currently dismantled submarines by 2005. To achieve this, the Russian government plan holds, the Russian federal budget will cover thirty to forty percent of the cost, reusable materials will cover twenty to thirty percent of the cost, and the remaining cost will be covered by international assistance. However, Russia's ability to fund the program as estimated remains questionable.[157]

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[155] Moltz and Robinson, "Dismantling Russia's Nuclear Subs: New Challenges to Non-Proliferation," 13.

[156] Ibid.

[157] Moltz and Robinson, "Dismantling Russia's Nuclear Subs: New Challenges to Non-Proliferation," 13.

Since the breakup of the Soviet Union in 1991, the United States and other Western nations have provided financial assistance to the Russian government to help with the dismantlement process. However, the majority of this assistance has been for the dismantlement of Russia's SSBNs, particularly the removal of the missiles and the destruction of the missile tubes. No assistance has been given for the dismantlement of the reactors on the SSBNs, nor is there any program to address any portion of the dismantlement of the SSN force, which is the predominant environmental concern in the Northern Fleet. According to Russian Admiral Yurasov, Head of the Navy's Nuclear Safety Inspectorate for Nuclear Installations, the latter issues are currently in the working group stage.[158]

B. FOREIGN ASSISTANCE PROGRAMS

With its economic and political problems, Russia has become dependent upon foreign assistance to maintain its nuclear submarine dismantlement program. The United States has provided the greatest amount of assistance, while Norway, the European Union, and a few other countries and institutions have provided assistance for related programs.[159] Norway and the other Scandinavian countries are predominantly concerned with the environmental issues associated with the Northern Fleet's dismantlement program, while the United States is more interested in the strategic concerns of promoting SSBN dismantlement and preventing nuclear proliferation.[160]

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158 Admiral Yurasov was a guest speaker at a symposium addressing dismantlement issues held at the Monterey Institute for International Studies on 12 December 1999.

159 Moltz and Robinson, "Dismantling Russia's Nuclear Subs: New Challenges to Non-Proliferation," 13.

160 James Clay Moltz, "Naval Fuel Cycle Foreign Assistance Overview," September 1999, Available [Online]:<http://www.cns.miis.edu/db/nisprofs/russia/naval/forasst/forasovr.htm. [10 January 1999].

1. The United States

The two U.S. programs fall under the Nunn-Lugar Cooperative Threat Reduction (CTR) Program, administered by the Department of Defense (DOD), and the Material Protection, Control, and Accounting (MPC&A) Task Force, administered by the Department of Energy (DOE). Both programs were developed to reduce "the threat of leakage of weapons of mass destruction and their technologies from the former Soviet Union."[161]

> Early U.S. programs offered assistance for missile and warhead dismantlement and provided technology to three shipyards to assist in SSBN dismantlement. It must be kept in mind that Russian shipyards had not previously engaged in submarine dismantlement and were therefore learning from scratch from U.S. contractors, some of which had no experience in nuclear submarine dismantlement work either. The U.S Navy provided only tacit support for the program, although later the U.S. Navy Sea Systems Command did allow Russian Navy and shipyard representatives to visit the main U.S. submarine dismantlement facility.[162]

Originally, CTR focused its submarine efforts on the dismantlement of the ballistic missile launchers (that is, the SSBNs) and the dissemination of dismantlement technology to the three shipyards designated by the START I treaty for dismantling SSBNs. Two of the three facilities are located in the Northern Fleet, Nerpa (Murmansk) and Zvezdochka (Serverodvinsk). This technology included nearly $7 million worth of baler shears, oxyacetylene torches, cranes, protective equipment, and other instruments used in the dismantling of nuclear submarines.[163]

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161 Moltz and Robinson, "Dismantling Russia's Nuclear Subs: New Challenges to Non-Proliferation," 13.

162 James Clay Moltz, "Assessing U.S. Assistance Programs for Submarine Dismantlement and the Naval Fuel Cycle," (Discussion paper prepared for a conference in Monterey California, 12 December 1999) Monterey Institute for International Studies, 4.

163 Ibid.

Although some U.S. equipment was now in place to propel the dismantlement program, CTR faced the problem of striking shipyard workers who now had equipment, but were not being paid. According to Alexei Arbatov, given the needs of impoverished shipyard workers, "the beautiful U.S equipment did not bring them any happiness."[164] One shipyard worker stated,

> We will arrange another Chernobyl...you will get the second Chernobyl here in the North. More frightening than the first one. Do remember, we have nuclear-powered subs on our hands.[165]

Hence, CTR undertook a major program review that would eventually lead to a program to provide direct contracts to shipyards for dismantlement work on a "deliverables" basis. This would provide funds for work completed, much like that of U.S. contractors. Under this new program, shipyards have been able to pay their workers after years of layoffs and decline.[166]

The MPC&A Program focuses its efforts on better ways to assist Russia in protecting weapons grade nuclear materials, including fresh naval fuel. There have been some delays, however, because of spent fuel problems. As previously mentioned, most of the decommissioned nuclear submarines have not been defueled and cannot be defueled due to the lack of storage space. Because the MPC&A Program was originally chartered to furnish technical and financial assistance for the protection and

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164 Arbatov quoted in ibid.

165 Igor Kudrick, "We will arrange another Chernobyl," Bellona foundation 1997. Available [Online]:<http://www.bellona.no/e/russia/nfl/news/971109-2.htm.

166 Moltz, "Assessing U.S. Assistance Programs for Submarine Dismantlement and the Naval Fuel Cycle," 4.

accountability of fresh naval fuel to avoid possible diversion, it was unable to deal with the issue of spent fuel storage. As Tamara Robinson has observed,

> Since spent fuel is less of a proliferation threat, it has not received as much attention from a storage prospective, and has become a limitation in the current U.S. approach. This limitation and lack of foresight has caused delays in implementing the programs that do fulfill direct U.S. objectives, such as [nuclear] submarine dismantlement.[167]

There has been some progress in regard to these storage issues. DOE has been working with Russian officials to complete a new storage facility for highly enriched uranium (HEU), site 49 on the Kola Peninsula near Severodmorsk, as well as improvements to the PM-12 and PM-63 ships used for storage of nuclear material.

It should be noted that neither of these programs is concerned with the environmental issues associated with the backlog of decommissioned Russian SSNs, even though the Russian government, recognizing the environmental risks of the SSNs and its own inability to dismantle them, has requested U.S. assistance to address the problem. Accordingly, U.S. equipment left from the SSBN dismantlement should arguably be used for continued SSN dismantlement, but the U.S. National Defense Authorization Act, Public Law 104-201 of 23 September 1996, states that CTR funds may not be expended or obligated to provide "assistance to promote environmental restoration."[168] Likewise, the DOE MPC&A projects apparently fall under similar guidelines. The reason why U.S. legislation regarding CTR assistance programs expresses little interest in the dismantlement of Russian SSNs and their threat to the

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[167] Robinson, "Submarine Dismantlement and Material Storage Challenges for Russian Nuclear Propulsion," 13.

[168] FY97 National Defense Authorization Act, Public Law 104-201, Title XV, Sec. 1503, 23 September 1996.

environment may be the lack of strategic concern. This would support the astute observation of Clay Moltz:

> To date, SSN dismantlement has been treated as largely an "environmental" issue, not one of strategic concern due to the absence of strategic missiles on these vessels. However, SSNs can be fitted with nuclear-tipped cruise missiles and torpedoes, as well as housing two reactors with HEU fuel, making them a proliferation threat as well as an object of possible terrorism.[169]

2. Norway

Because of its concerns about nuclear safety and radioactive waste contamination, the Norwegian government has contributed nearly $30 million in assistance to the Russian nuclear submarine dismantlement program. Norway's assistance package is designed to address four priority areas: submarine dismantlement, material storage problems, weapons-related contamination, and spent fuel and radioactive waste management. Norway also plans to assist in the construction and improvement of spent fuel rail cars and spent fuel transport vessels. (This project is currently being assessed by the Arctic Military Environmental Cooperation (AMEC) Program.)[170]

Additionally, Norway is participating in a trilateral project with the United States and Russia to construct adequate treatment facilities to handle the increased amounts of LRW from decommissioned nuclear submarines.[171]

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169 Moltz, "Assessing U.S. Assistance Programs for Submarine Dismantlement and the Naval Fuel Cycle," 8.

170 Robinson, "Submarine Dismantlement and Material Storage Challenges for Russian Nuclear Propulsion," 15.

171 Moltz, "Naval Fuel Cycle Foreign Assistance Overview."

3. European Union (EU) Countries

The Finnish government had contributed $700,000 to a Finnish company to treat liquid radioactive waste (LRW) from the Northern Fleet icebreakers, but discontinued further funding for similar projects, designed to treat the LRW of Russian nuclear submarines, when it was discovered that these funds were being used by Moscow to support Northern Fleet military vessels.[172]

The United Kingdom has committed nearly $5 million to improve Russia's capability to safely handle radioactive waste resulting from the dismantlement process. Most of this aid addresses the removal of spent fuel rods from the service ship *Lepse.* The United Kingdom is also involved in an international consortium with the governments of Sweden, France, and Russia to develop an interim storage facility for spent naval fuel at the processing plant in Mayak.[173]

The condition of the service vessel *Lepse***,** which contains seriously damaged fuel elements, is of particular concern for those addressing the Northern Fleet crisis.

> This multilateral project, involving Norway, the US, France, and the European Union, aims at removing the damaged fuel elements and improving the safety of the *Lepse.* The first stage of this project will cost $9 million, which is being split among the parties. This work is part of the long-term cooperative efforts planned by the Euro-Arctic Barents Council, which includes Norway, Sweden (an EU member), and Russia, among other parties, in cooperation with the United States and France. France, Norway, and the EU are also involved in other cooperative assistance outside the submarine field. One project is aimed at the shutdown of two unsafe, VVER-440 civilian reactors operating on the Kola Peninsula.[174]

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[172] Ibid.

[173] Moltz and Robinson, "Dismantling Russia's Nuclear Subs: New Challenges to Non-Proliferation," 14.

[174] Moltz, "Naval Fuel Cycle Foreign Assistance Overview."

Lastly, a consortium of companies from Sweden, the United Kingdom, France, Norway, and Russia has agreed to design two modern storage facilities at Mayak to store spent fuel generated by the dismantlement of nuclear submarines in the Northern Fleet.

C. CONCLUSION

The downward spiral of Russia's economy and political system as well as a complete lack of foresight have created a nuclear "nightmare" on the Kola Peninsula. Although extensive external assistance has been provided to the Russian government to aid in the nuclear submarine dismantlement program, the process still proceeds at a snail's pace. The causes of this slow pace include "mutual mistrust, the absence of liability agreements and Russian denial of access to certain facilities."[175]

According to Clay Moltz and Tamara Robinson,

> The greatest need in Russia today is for Russia to develop a cradle-to-grave system for submarine dismantlement that provides for integrated processing of submarines through the combined efforts of several facilities. Russia's huge size will likely require parallel dismantlement processes to accommodate both the Northern and Pacific Fleets, rather than making use of a single dismantlement facility.[176]

Russia's lack of interest in the environmental issues related to the dismantlement of Northern Fleet nuclear submarines should be a matter of grave concern for the United States and other nations. The Chernobyl case study clearly indicates what could happen if the dismantlement program is not carried out with appropriate safety and environmental precautions. It appears that a political "band-aid" has been placed on environmental issues while a political "tourniquet" has been applied to issues that are

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175 Moltz and Robinson, "Dismantling Russia's Nuclear Subs: New Challenges to Non-Proliferation," 14.

176 Ibid.,15.

perceived as being of greater strategic importance. This attitude is evident in the views attributed to Vice Admiral Nikolai Birillo, the Russian Admiral in charge of the committee to dismantle nuclear submarines. According to the Associated Press, "Vice Adm. Nikolai Birillo was trained to end the world, not clean it up."[177]

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[177] Associated Press dispatch, "West Helps Dismantle Russia Subs," 10 November 1999.

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GLOSSARY

Curie (Ci)	Unit of radioactivity, measured in terms of the rate of radioactive decay, equeling the quantity of radioactive material that undergoes 3.7×10^{10} spontaneous nuclear transitions per second. Also equals the activity of one gram of radium-226.
Becquerel (Bq)	The International Systam of Units (SI) derived unit of activity. One Bq is activity of a radionuclide decaying at thr rate of one spontaneous nuclear transition per second. Thus, 1 Ci = 3.7×10^{10} Bq.
Gray (Gy)	The International System of Units (SI) derived unit of absorbed dose. One Gy equals the energy per unit mass imparted to matter by ionizing radiation of one joule per kilogram. 1 Gy = 100 rad.
rad	Unit of absorbed dose corresponding to the absorption of 100 ergs of ionizing radiation (thus not limited to X- or gamma radiation) in one gram of any material at the place of interest.
rem	Unit or dose equivalent, where 1 rem is the amount of ionizing radiation of any type that produces the same damage in the human tissue as one rad of X-radiation at a defined energy.
roentgen	Unit of radiation defined in terms of the quantity of X- or gamma that produces the same number of ions pairs in one cubic centimeter of dry air that would be produce by one gram of radium at a specified distance.

Bq	Becquerel, 1 nuclear disintegration/sec.
Ci	Curie
Gy	Gray, unit of radiation absorbed dose, equals 100 rad
hr	hour
kg	kilogram
m	meter
Mci	megacurie
MT	metric ton
R	roentgen
PBq	measurement of Ci (MCi x 37.0 = PBq)

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